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The NPARC Alliance: A Science and Technology/Test and Evaluation Partnership Example

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May 2000

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Abstract

The NPARC Alliance is a partnership between NASA's Glenn Research Center , the Air Force's Arnold Engineering Development Center, and industry. We have been working together since the early 90s to produce flow solvers for use in advanced aerospace applications. This flow simulation system (WIND) is continuously being improved and validated by the NPARC Alliance to address the U.S. aerospace community's requirements for an efficient general-purpose tool. The Alliance provides support to all user organizations, serves as the national focal point for NPARC software development/validation, and ensures that these efforts remain customer focused by actively seeking feedback from the user community. This paper provides an overview of the capabilities of the NPARC Alliance simulation system, a description of the development process, and discusses the history and progress of the Alliance to date.

Introduction

The NPARC Alliance began with an inlet computational fluid dynamics (CFD) peer review held at NASA Glenn Research Center (GRC) in early 1992. At that time both Gerald Paynter from Boeing-Seattle and Ray Cosner from Boeing-St Louis, then McDonnell Douglas, suggested that the goals of Glenn's Proteus code development and those of the AEDC's PARC code were similar. This was followed by a chance meeting between two civil servants from Arnold Engineering Development Center (AEDC) and NASA GRC at a government short course in March 1992. The result was the creation of the NPARC Alliance. The NPARC Alliance draws on the unique talents and qualifications of its partners while at the same time soliciting the experience and insights of government, industrial, and academic users to ensure that code development proceeds in a cost-effective, customer-responsive manner.

There are many references available on the PARC and NPARC codes (Bruns and Smith 1994; Chaing and Hunter 1994; Georgiadis, Drummond and Leonard 1994; Mayer and Paynter 1994; Power, McClure and Vinh 1994; Cooper and Sirbaugh 1990), but in a nutshell, the NPARC Code is a general-purpose, Navier-Stokes code. It will handle inviscid/viscous, laminar or turbulent, steady-state or transient flows.

A major effort was undertaken last year to combine the capabilities of the NPARC code version 3.0, the NXAIR code used at AEDC for store separation, and the NASTD code in wide use at Boeing-St Louis into the WIND (Bush Power and Towne 1998) code. The combined capabilities of these three codes was a major step forward towards meeting the needs of the users at all locations. Some of the features of the WIND code are:

- Improved Graphical User Interface
- Moving Grid Capability
- Improved/Expanded Documentation
- Emphasis on Portability/Maintainability
- Advanced Time-Accurate Solution Method
- Block and Chimera Interface

In Fiscal Year 1998 the Alliance began working with the High Performance Computing Modernization Program, Common High Performance Computing Software Support Initiative (CHSSI), and the Air Force Research Lab (AFRL). Under the CHSSI program, the NPARC Alliance is working to improve the solver to exploit scalable computing systems. This paper will describe the formation, organization, operation, and future of the NPARC Alliance itself and will present a few examples of collaboration with the test and evaluation (T&E) community.

Background

In the late 1970s a doctoral research effort at NASA Ames Research Center resulted in the development of the Ames Research Code (ARC). ARC was a general-purpose Navier-Stokes flow solver. In the mid-1980s AEDC acquired ARC and began tailoring the code to use as a production code for propulsion ground test and other related activities. This new code was called PARC. By the late 1980s, PARC had found wide usage throughout government, academia, and industry as a state-of-the-art, general-purpose, useable production code that had the added benefit of being available at no cost. Each user treated the code as a local asset, and code improvements and documented uses were often not publicly shared. There was no established method of collecting and incorporating new code developments or noteworthy modifications into a central baseline code that was documented, supported, and validated. Figure 1 depicts a timeline of the events involved in PARC's development leading to the formation of the Alliance.

Two of the leading users and developers of PARC, AEDC and GRC, began discussions in the early 1990s about the need to transition PARC from a local asset into a nationally useful, documented, supported, and validated CFD tool for commercial, academic, and government users. To formalize the alliance, a Memorandum of Understanding (MOU) was signed by the director of GRC and the commander of AEDC in July 1993. This MOU acknowledged that both centers worked in the development of complementary technologies and could each benefit from future cooperation. It was followed by an Annex to the MOU in September 1993 that specifically addressed the NPARC Alliance. Since that time the NPARC Alliance has been used as a model for cooperation between the two centers, resulting in MOU Annexes and partnerships in the technical areas shown in Fig. 2.

The Alliance had to be formed with the understanding that the missions of NASA GRC and AEDC are fundamentally different but complementary in nature. The mission of

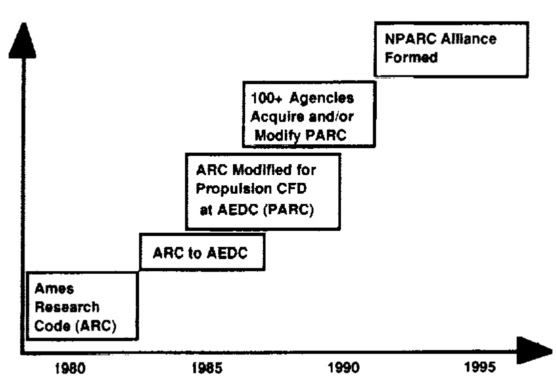

Fig. 1. NPARC origin.

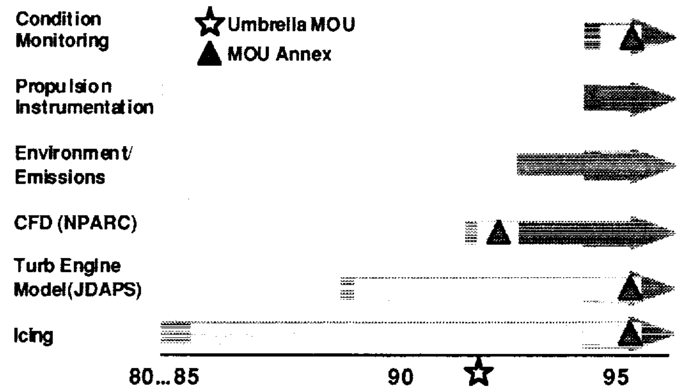

Fig. 2. GRC/AEDC Alliances.

NASA GRC is:

> As a diverse team working in partnership with government, industry and academia to increase national wealth, safety and security, protect the environment, and explore the universe.
>
> We develop and transfer critical technologies which address national priorities through research, technology development and systems development for aeronautics and space applications.

The mission of AEDC is:

> To provide the world's most effective and affordable aerospace ground test products and services to our customers.
>
> To ensure ground test facilities, technologies, and knowledge are viable for today's and tomorrow's customers.

Although the two center missions were different, their accomplishment has grown to depend more and more upon the use of state-of-the-art CFD. The two centers were also experiencing budget cuts, which encouraged collaboration on technology development efforts. Since no existing codes could be found to meet the needs of the two centers, development efforts have been underway at each facility for several years.

The Alliance's purpose is consistent with the missions of the two centers and is captured in the following Vision and Mission statements:

Vision

The Computational Tool of Choice for Aerospace Flow Simulation

Mission

Develop, validate, and support an integrated, general-purpose, computational flow simulator for the U.S. aerospace community.

Collaborate with users to ensure that this simulation capability is the system of choice in the analysis, design, and development of aerospace vehicles and components.

The Vision and Mission statements are used to balance the near- and far-term goals of the Alliance. We have found it key to the health of the Alliance to keep a clear focus on our goals as put forth in these statements.

Organization/Operation

To achieve the vision and support the mission, the Alliance was structured to take advantage of each agency's strengths and abilities (Fig. 3).

The Executive Direction Committee consists of one manager from each Alliance partner (AEDC and GRC). The Technical Liaisons lead the technical efforts at the two centers, supported by the Technical Direction Committee. This Committee is made up of one technical representative from each center in the three functional areas of the alliance: Support, Development, and Validation.

The NPARC Association is a self-governing group consisting of government, industry, and academic users. Any NPARC user who signs an NPARC Software Release Form (available in the Policies and Plans of the NPARC Alliance 1997) becomes a registered NPARC user and is eligible to be an Association member. A Steering Committee, drawn from the NPARC Association, is chartered by the Alliance to formalize users' inputs and provide feedback to the Alliance regarding current and future code developments. The current Association Steering Committee is co-chaired by representatives from Boeing-Seattle and Boeing-St Louis. The NPARC Association plays a key role in providing user community feedback to the Alliance to ensure NPARC remains useable, current, and relevant.

The Alliance structure is designed to facilitate participation by all members and to make use of their unique talents. For example, this organizaton takes advantage of the fact that GRC is strong in the areas of code development and validation and has made tremendous contributions to the code's turbulence modeling capabilities. AEDC is strong in areas of development and support and responsible for much of the user-friendly nature of the code. Our industry representatives are strong in each of these three areas. One key to the Alliance's success to date has been the understanding that the cultures at AEDC, GRC, and industry are very different. Although this can be frustrating at times, the team members have learned, and continue to learn, to value the differences. Because of the differences in organizational mission, layout, mode of operation, educational background, and even geographical locations, we rarely see issues in a similar manner, yet we are all working towards a common vision and mission. The result has been that when the Alliance is presented with a challenge, we are able to come up with a much wider range of solution options than would normally be the case. The second key to the Alliance is communication, both internal and external.

A primary method for internal communication is the Annual Plans and Policy Document mentioned above. This document outlines the current Vision and Mission statements, as well as the current organizational structure. It also provides the forms required to obtain a copy of the code from the Alliance. However, the real meat of the document is the schedules for each of the three areas: development, validation, and support. These schedules are negotiated each year and define the expectations from each of the Alliance partners for the upcoming two years. An example of the validation schedule is shown in Fig. 4.

The Alliance has made extensive use of the video teleconference facilities at both centers. On roughly a monthly basis,

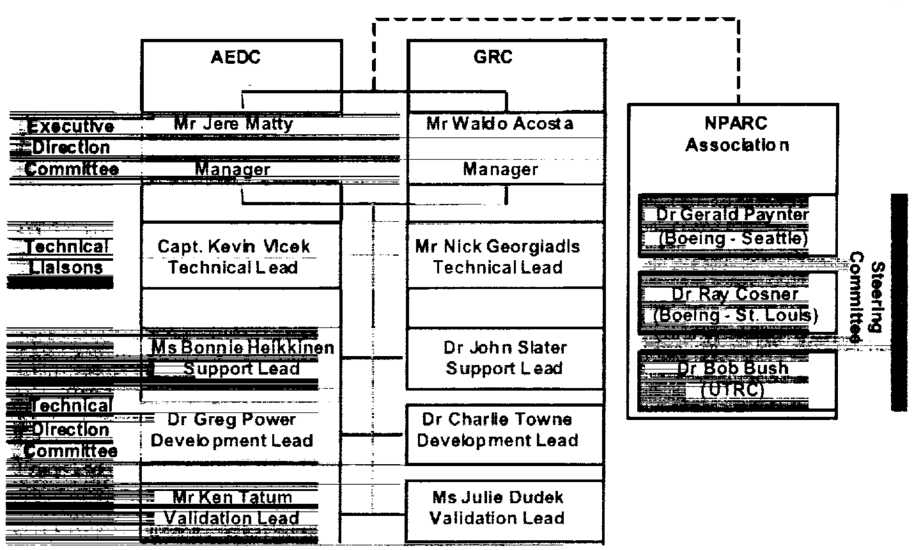

Fig. 3. NPARC Alliance organization.

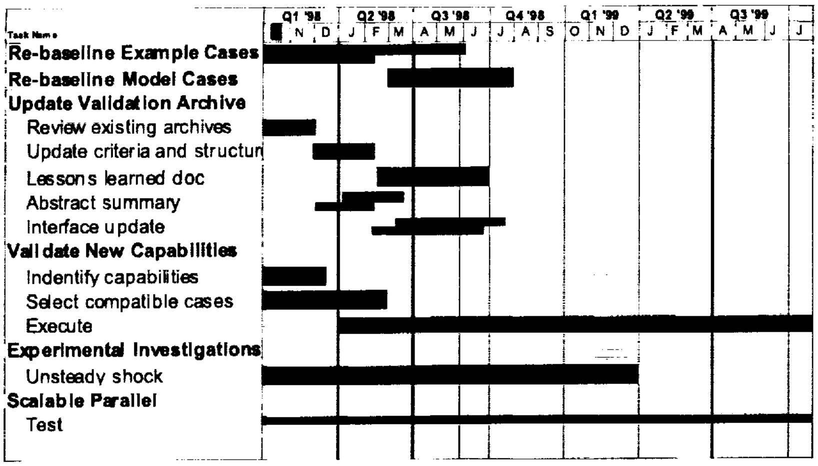

Fig. 4. Plans and policy schedule.

we meet in "two dimensions" with the principal players from each center and "pipe in" our key industry representatives from Boeing and United Technology Research Center (UTRC), i.e., they are connected by audio only. A key item on the agenda at these meetings is the review of progress on the three schedules in the current year's plans and policy document. Any business related to the Alliance is also discussed in these meetings to include issues both technical and managerial in nature. We also have frequent trips to the two centers and occasional trips to the Boeing facilities. One of the key internal communication methods has become the annual NPARC Workshop. The first of these took place at the Sheraton Hotel at the Cleveland airport, but subsequent workshops have been held at the Gossick Leadership Center (GLC) located at AEDC.

The GLC is a unique facility designed to host planning sessions. Based on the Scan, Focus, Act model, the participants scan the environment for changes that will affect mission accomplishment, focus on what they can actually do to take advantage of the new situations, then schedule specific actions to deal with them. To foster creative thinking, the meetings have a playful atmosphere that can even involve exercises using building blocks.

Alliance Results

The results of these workshops are the draft for the next year's Plans and Policy Document. This document is finalized following the workshop and presented at the NPARC Users Meeting, held in conjunction with the annual AIAA Aerospace Sciences meeting. This meeting is a key part of our external communications.

External communications follow multiple paths. The semi-annual newsletters, alternately titled *The Predictor* and *The Corrector*, distribute Alliance news of interest to all users and stakeholders. We also sponsor NPARC Technical Sessions at conferences including three sessions at the AIAA/SAE/ASME/ ASEE Joint Propulsion Conference and four sessions at the AIAA Aerospace Sciences Conference and Exhibit. We have also sponsored an NPARC Session at the Applied Aero Conference. At each of these conferences we hold NPARC Users Meetings to keep our users aware of our status in the three areas of Development, Validation, and Support, as well as solicit feedback. Twelve User's Meetings have been held to date.

User surveys are also used to solicit user input to the Alliance. Two were conducted by mail, and the third is now underway electronically via our NPARC Web Site (http://www.arnold.af.mil/nparc/). Figure 5 presents results of the electronic survey.

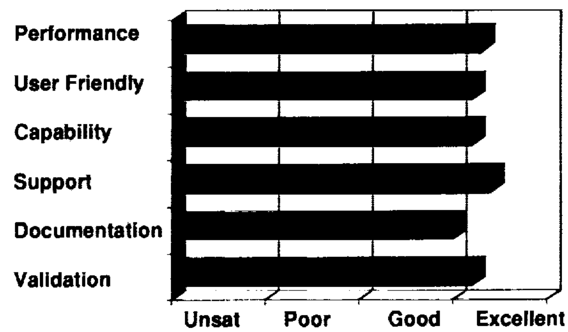

Fig. 5. User survey results.

The web site has been a key to external communication and contains the Alliance Vision/Mission statements, description of the flow simulator, the forms required to acquire the code, all documentation to include the user's guide in hypertext format, and application summaries (Fig. 6).

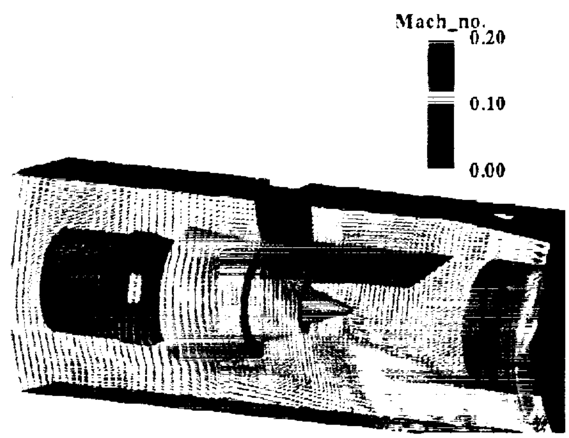

Fig. 6. Solution from applications summary.

The Validation Archives are also available on the web site; these cover all code validation activities. Also available is The NPARC Technical Report Server (TRS), a searchable database of technical papers dealing with the application, development, and validation of the code. A hot news section of the site is maintained to distribute bug fixes and 'hot' information. Also available are the Alliance Newsletters and a User's Bulletin Board. The bulletin board is used to communicate with the developers of NPARC or other users of the code. Finally, links are provided to pre- and post-processor tools for use with the solver. Communication statistics are gathered by the support team and displayed at the monthly VTCs (Fig. 7).

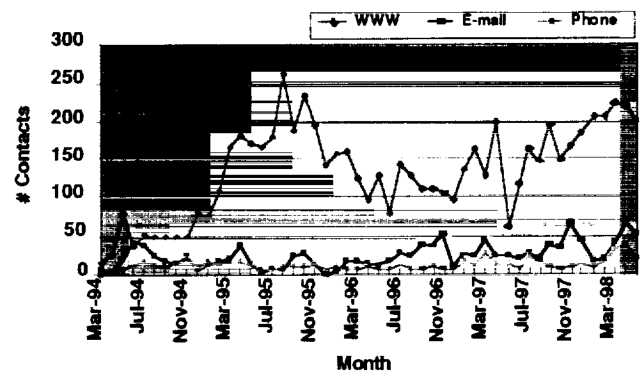

Fig. 7. NPARC communication statistics.

The support team also maintains a database of those requesting the code and their organizations (Fig. 8). Note that the largest number of those requesting the code come from U.S. industry.

To date, over 700 requests for the code have been processed representing over 300 different organizations. The users represent all three branches of military service, every major aerospace firm, and a wide range of universities. The Alliance is structured such that any improvements to the code made by a user can be submitted for inclusion in the official version-controlled code. This is not uncommon and has resulted in seven major releases of the code since the start of the Alliance.

S&T/T&E Partnership Examples

Throughout the years, CFD has been used not only as an isolated analysis and design tool, but in partneship with test and evaluation. It has helped solve unforseen problems that surfaced during the T&E phase, develop more efficient and cost-effective test plans, and solve operational problems.

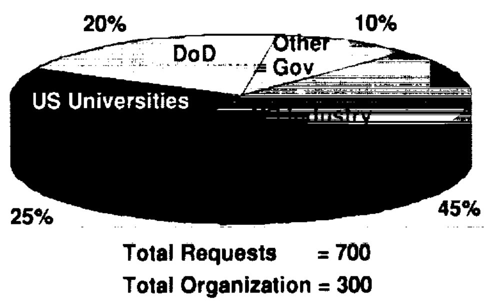

Fig. 8. Code requests statistics.

An example where CFD, and in particular the NPARC Alliance flow solver, helped during a T&E program was the F-15 Exhaust Gas Management System (EGMS) test program. The EGMS was designed to capture the exhaust gases during the engine reverse mode and to direct it into the test cell exhaust system. Subscale tests indicated the EGMS system was not capturing all the reverse flow from the engine. A solution was needed before the full-scale engine test could begin.

The NPARC code was used to verify the subscale test and to propose and evalute a modified EGMS. The analysis verified the spillage observed in the subscale test (Fig. 9). Analysis of the design modification indicated that the spillage was eliminated (Fig. 10). The design modifications were incoporated into the full-scale model and it performed as predicted.

The Army's Aviation Applied Technology Directorate (AATD) needed to reduce the risks and costs associated

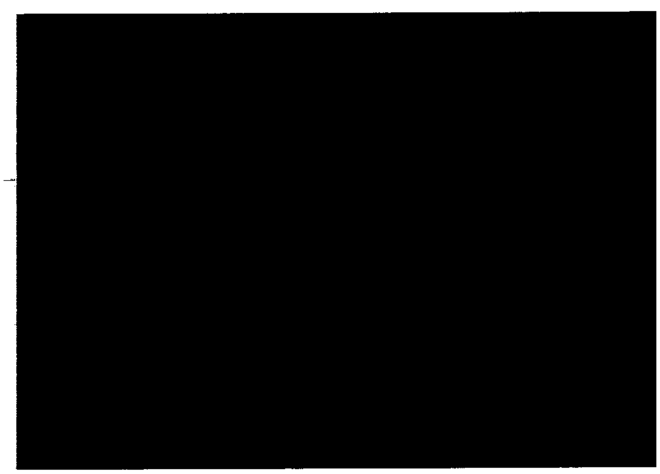

Fig. 9. F-15 S/MTD Exhaust Gas Management System, spillage observed.

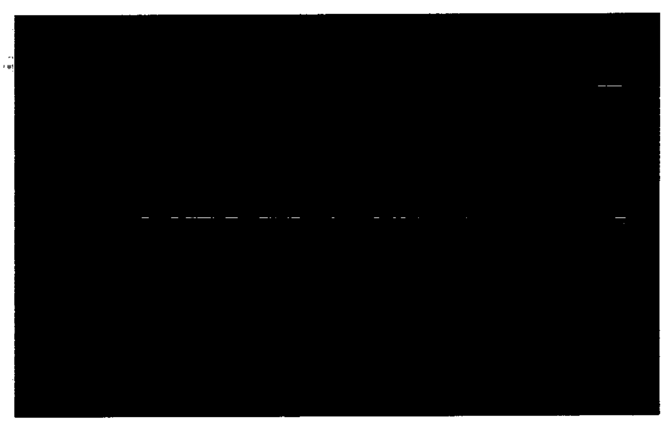

Fig. 10. F-15 S/MTD Exhaust Gas Management System, spillage eliminated.

with the development of an advanced infrared suppressor nozzle for the Apache helicopter (Fig. 11). They used the NPARC code to evaluate various design configurations and to select the most promising concept for experimental evaluation. The analysis indicated that the temperature distribution provided by the lobed mixer nozzle was the best configuration for their application.

Fig. 11. IR suppressor exhaust temperature distribution.

CFD has also been used to assess the test cell effects on engine performance and reduce model construction time in AEDC's Aeropropulsion Systems Test Facility (ASTF) (Fig. 12). The NPARC code was used to optimize the following test cell parameters: diffuser diameter/orifice size, diffuser axial position, screen porosity, screen structure support, and cell cooling flow. This optimization helped enhance the overall quality of the test cell results.

The Navy was experiencing an uncommanded rolling called "wing drop" during the development of the new F-18 Super Hornet. The problem represented a safety hazard for the pilot, and the Navy faced program cancellation and the loss of a superior tactical capabilty. The WIND code was used to anaylze and understand the wing airflow that was causing this condition and to offer sugestions for potential solutions (Fig. 13).

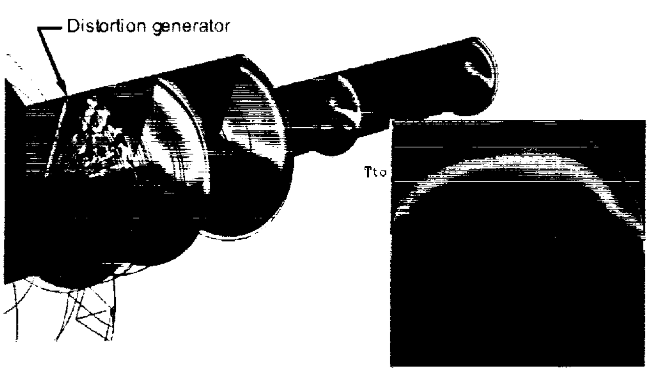

Fig. 12. Engine test cell temperature distortion generator.

These are just a few examples of where the S&T and T&E partnership have worked together to find cost-effective solutions to real problems.

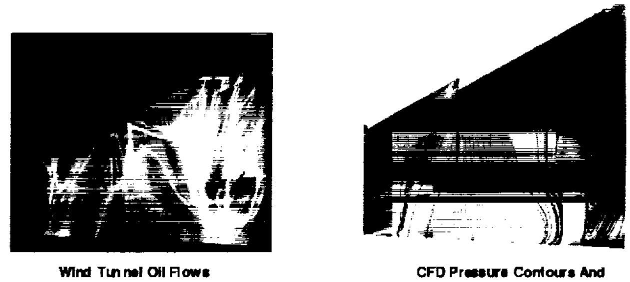

Fig. 13 F/A-18E/F wing drop analysis.

Challenges

So far we have failed to discuss many of the challenges faced by the Alliance in getting to where we are today. They include:

- Yearly funding issues at each of the participants' organizations
- Division of responsibilities in the Plans and Policy Document
- Deciding how much of the CFD problem to tackle, i.e., solver only or CADCAM to engineering units
- Integration with CFD work going on at other NASA and DoD centers
- Incorporation of more advanced technology (like unstructured gridding)

Even settling on the definition of the Alliance acronym (NPARC) and a name for the present solver (WIND) were not trivial tasks! But we have been successful to date due to the tremendous efforts of all the Alliance members who have come to realize that we are more productive as a team than we ever could be alone.

Future Plans

The annual workshop continues to be a big success and invaluable for charting the Alliance's course for the future. Each year the Alliance finds itself at a crossroad, reshaping its structure and refining its path. This year is no different. Expanding the Alliance through the participation of other government and industry members seems paramount if the Alliance is to remain viable. Moving to a modular framework to take advantage of new technologies like unstructured grids is also a strong theme that resulted from the workshop.

We are looking forward to strengthening the Alliance in the coming year as we explore ways to increase participation by other government and industry teams. The new ideas that will come from a redefined alliance will benefit all members through increased capabilities and better technology transfer.

Summary

The development and application of CFD has become a key to the success of the NASA GRC, AEDC, and aerospace industry. The NPARC Alliance has been successful to date in leveraging the capabilities of both government and industry. The keys to its success include overcoming fears of working with people from different company cultures and backgrounds. The Alliance members have learned to value the differences and focus on a well-defined mission statement and organizational structure to get things done. Detailed plans and realistic schedules tie the responsibilities to specific efforts to be accomplished in fulfilling the mission.

No alliance could function properly without effective communication, and the NPARC Alliance has a thorough communication network, both formal and informal, at multiple levels. The formation of the NPARC Association and its interface to the Alliance are critical to maintaining NPARC as a useable code containing the state-of-the-art features that the users deem important. Open communication forums like the Users' Association Meetings, the World Wide Web Home Page, and Internet e-mail help maintain timely and accurate collection and dissemination of current news and code status.

The result has been an organization that develops, validates, and supports a code that has found wide application throughout government, industry, and academia. Current plans to expand the Alliance through the participation of other government and industry members, move to a modular framework, and take advantage of new technologies like unstructured grids, should further increase its effectiveness in solving the increasingly complex problems presented by the present times.

The NPARC Alliance computational tools have been used extensively to support Test & Evaluation work in both Government and industry. It made signinficant impact on the the development of the F-15, the Apache helicopter, and the F-18 programs.

Additional Information

The Policies and Plans of the NPARC Alliance is a publicly available document that summarizes the philosophy and organization of the NPARC Alliance (Polices and Plans of the NPARC Alliance 1997). It also addresses the guiding policies for the support, development, and validation technical efforts in separate sections. Included in the policies are program plans and schedules addressing the activities planned within each technical area. These plans are continuously reviewed and formally updated annually to reflect the current goals and directions of the Alliance. The program plans also indicate which Alliance partner is responsible for which activities. The document also includes instructions for obtaining NPARC and a copy of the Proprietary Protection Agreement.

Further information on the NPARC Alliance is also available through the World Wide Web at http://www.arnold.af.mil/nparc/ or by e-mailing a request for information to nparc- support@info.arnold.af.mil.

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13. ABSTRACT ***(Maximum 200 words)***

The NPARC Alliance is a partnership between NASA's Glenn Research Center, the Air Force's Arnold Engineering Development Center, and industry. We have been working together since the early 90s to produce flow solvers for use in advanced aerospace applications. This flow simulation system (WIND) is continuously being improved and validated by the NPARC Alliance to address the U.S. aerospace community's requirements for an efficient general-purpose tool. The Alliance provides support to all user organizations, serves as the national focal point for NPARC software development/validation, and ensures that these efforts remain customer focused by actively seeking feedback from the user community. This paper provides an overview of the capabilities of the NPARC Alliance simulation system, a description of the development process, and discusses the history and progress of the Alliance to date.

14. SUBJECT TERMS
Computational fluid dynamics; NPARC; Navier-Stokes equation; Applications programs; Computers; Flow solver

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